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[0017]

[Embodiments of the Invention]

Figure 1(a) is a perspective view showing an embodiment of a laminated type piezoelectric element made of a laminated type piezoelectric actuator according to the present invention, and Figure 1(b) is a longitudinal sectional view along A-A' in Figure 1(a).

[0018]

The laminated type piezoelectric actuator of the present invention has, as shown in Figure 1, a quadratic prism state element body 3 comprising an active part 8 formed by alternately stacking a plurality of piezoelectric bodies 1 and a plurality of internal electrodes 2 and an inactive part 9 provided outside the active part 8 in the lamination direction.

[0019]

The internal electrodes 2 have the ends alternately exposed to opposing side faces of the element body 3 (external electrode formed face), a conductive portion 4a is formed at respective exposed portions of the internal electrodes 2, and a metal plate 4b is bonded to these conductive portions 4a so as to constitute an external electrode 4.

[0020]

By this, the internal electrodes 2 are electrically connected to each of the external electrodes 4 alternately, while the end of the internal electrode 2 which is not connected to the external electrode 4 is covered by an insulator 10. Moreover, a lead wire 16 is connected and fixed to the external electrode 4 by solder or the like.

[0021]

For the piezoelectric body 1, a piezoelectric ceramic material mainly consisting of lead zirconate titanate, Pb (Zr, Ti) O_3 (hereinafter abbreviated as PZT) or barium titanate, $BaTiO_3$, is used, for example, but not limited to them, any ceramics with piezoelectric property may be used. It is desirable that the piezoelectric body material has a high piezoelectric distortion constant d_{33}.

[0022]

Moreover, the thickness of the piezoelectric body 1, that is a distance between the internal electrodes 2 is desirably 0.05 to 0.25 mm in view of size reduction and application of a high electric field. This is because, though the number of laminations is increased in order to obtain a larger displacement amount by applying a voltage for a laminated type piezoelectric element, if the thickness of the piezoelectric body 1 in the active part 8 is too thick when the number of laminations is increased, size and height of the actuator can not be reduced, while if the thickness of the piezoelectric body 1 in the active part 8 is too thin, it might easily lead to insulation breakdown.

[0023]

Moreover, a groove with the depth of 50 to 500 μm and the width of 30 to 200 μm in the lamination direction is formed on every other layer on the external electrode 4 formed surface on a side surface of the active part 8 in the element body 3, and the insulator 10 is formed by filling glass, epoxy resin, polyimide resin, polyamide-imide resin, silicon rubber or the like in this groove. The ends of the internal electrodes 2 are insulated by the insulators 10 alternately filled in the groove, and the other non-insulated ends of the internal electrodes 2 are connected to a metal plate through the conductive portion 4a.

[0024]

It is necessary for the conductive portion 4a to contain silver or an alloy mainly consisting of silver for bonding by diffusion bonding with the internal electrode 2 and a glass component for bonding by diffusion bonding with the piezoelectric body 1. Also, it is desirable that silver or the alloy mainly consisting of silver is 40 to 90 volume% in the total amount to provide conductivity as the external electrode 4.

[0036]

Next, this laminated body is pressurized while being heated at 50 to 200°C to integrate the laminated body. The integrated laminated body is cut into a predetermined size, debinding is performed at 400 to 800°C for 5 to 40 hours, and glost firing is carried out at 900 to 1200°C for 2 to 5 hours so as to obtain a laminated sintered body to be the element body 3. The ends of the internal electrodes 2 are exposed on the side faces of this element body 3.

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